METHODS AND APPARATUS FOR PROVIDING TOUCH-SENSITIVE INPUT IN MULTIPLE DEGREES OF FREEDOM

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. patent application Ser. No. 08/696,366 filed on Aug. 13, 1996, now abandoned which is a continuation-in-part of U.S. patent application Ser. No. 08/509,797 filed on Aug. 1, 1995, now U.S. Pat. No. 5,729,249, which is a continuation of U.S. patent application Ser. No. 08/238,257 filed on May 3, 1994, now abandoned, which is a continuation-in-part of U.S. patent application Ser. No. 07/798,572 filed on Nov. 26, 1991, now U.S. Pat. No. 5,335,557, all of which are incorporated herein by reference. The present application also claims the benefit of U.S. Provisional Application No. 60/086,036, filed May 19, 1998, which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of input control devices. More specifically, it relates to force-sensitive input-control devices with multiple surfaces capable of providing intuitive input in one to thirty-six degrees of freedom.

2. Description of the Related Art

(a) Prior Art 3D and 6D Input Control Devices

Two-dimensional input control devices such as mice, joysticks, trackballs, light pens and tablets are commonly used for interactive computer graphics. These devices are refined, accurate and easy to use. Three-dimensional ("3D") devices allow for the positioning of cursors or objects relative to conventional X, Y and Z coordinates. Six-dimensional ("6D") devices are also capable of orienting or rotating objects. More specifically, 6D devices may provide position information as in a 3D device and further provide rotational control about each of three axes, commonly referred to as roll, pitch and yaw. However, current 3D and 6D input devices do not exhibit the refinement, accuracy or ease of use characteristic of existing 2D input devices. In fact, existing 3D/6D input devices are typically cumbersome, inaccurate, non-intuitive, tiring to use, and limited in their ability to manipulate objects.

One well known category of 3D computer controllers are the "computer gloves," such as the Power Glove controller distributed by Mattel, Inc. Similar devices include the Exos Dextrous Hand Master by Exos, Inc., and the Data Glove by VP' Research, Inc. These controllers are worn as a glove and variously include sensors for determining the position and orientation of the glove and the bend of the various fingers. Position and orientation information is provided by ranging information between multiple electromagnetic or acoustic transducers on a base unit and corresponding sensors on the glove. However, the user is required to wear a bulky and awkward glove and movement of these awkward controllers in free space is tiring. Further, these devices are typically affected by electromagnetic or acoustic interference, and they are limited in their ability to manipulate objects because of the inherent dissimilarity between the free-form movement of a glove and the more constrained movement of manipulated objects.

A second category of 3D/6D controllers are referred to as "Flying Mice." The Bird controller by Ascension Technology Corp. of Burlington, Vt. tracks position and orientation in six-dimensions using pulsed (DC) magnetic fields. However, it is affected by the presence of metals and also requires manipulating the controller in free space. The 2D/6D Mouse of Logitech Inc. is similar in function, but uses acoustic ranging similar to the Mattel device. The 3SPACE sensor from Polhemus, described in U.S. Pat. No. 4,017,858, issued to Jack Kuipers Apr. 12, 1977, uses electromagnetic coupling between three transmitter antennas and three receiver antennas. Three transmitter antenna coils are orthogonally arranged as are three receiver antennas, and the nine transmitter/receiver combinations provide three dimensional position and orientation information. However, all "flying mouse" devices require the undesirable and tiring movement of the user's entire arm to manipulate the controller in free space. Further, these devices are either tethered by a cord or sensitive to either electromagnetic or acoustic noise.

A device similar to the flying mice is taught in U.S Pat. No. 4,839,838. This device is a 6D controller using 6 independent accelerometers in an "inertial mouse." However, the device must still be moved in space, and the use of accelerometers rather than ranging devices limits the accuracy. Another inertial mouse system is taught in U.S. Pat. No. 4,787,051 issued to Lynn T. Olson.

A third category of 3D/6D controllers includes 3D/6D joysticks and trackballs. Spaceball of Spatial Systems, Inc. is a rigid sphere containing strain gauges or optical sensors to measure the forces and torques applied to a motionless ball. The user pushes, pulls or twists the ball to generate 3D translation and orientation control signals. Spaceball is described in detail in U.S. Pat. No. 4,811,608 issued to John A. Hilton Mar. 14, 1989. Similarly, the DIMENSION 6/Geoball controller distributed by CiS Graphics Inc. incorporates a 6-axis optical torque sensor housed in a spherical enclosure. The device measures translational forces and rotational torques. However, these devices are subject to a number of disadvantages. For example, it is difficult to provide for precise positioning, as there is no provision for the use of a stylus. Further, these devices are primarily controlled with hand muscles, rather than with the more precise finger muscles. Further still, these devices provide for only relative control and have no provision for providing an absolute origins or an absolute positions. They are therefor not suitable for providing closure in digitized 3D inputs. Finally, they are limited in their ability to provide an intuitive feel for 3D manipulation of a controlled object not specified in the Cartesian coordinate system. For example, they are not readily adaptable to spherical or cylindrical coordinate systems.

(b) Prior Art Force-sensitive Transducers

Force-sensitive transducers are characterized in that they do not require a significant amount of motion in order to provide a control input. These devices have appeared in a number of configurations, some of which are capable of sensing not only the presence or non-presence of the touch of a user's finger or stylus, but also the ability to quantitatively measure the amount of force applied. One such a device is available from Tekscan, Inc. of Boston, Mass. This device includes several force-sensitive pads in a grid-based matrix that can detect the force and position of multiple fingers at one time. Another force-sensitive device is available from Intelligent Computer Music Systems, Inc. of Albany, N.Y. under the TouchSurface trademark. The TouchSurface device can continuously follow the movement and pressure of a fingertip or stylus on its surface by responding to the position (X and Y) at which the surface is touched and to the force (Z) with which it is touched. Further, if two positions are touched simultaneously in the TouchSurface